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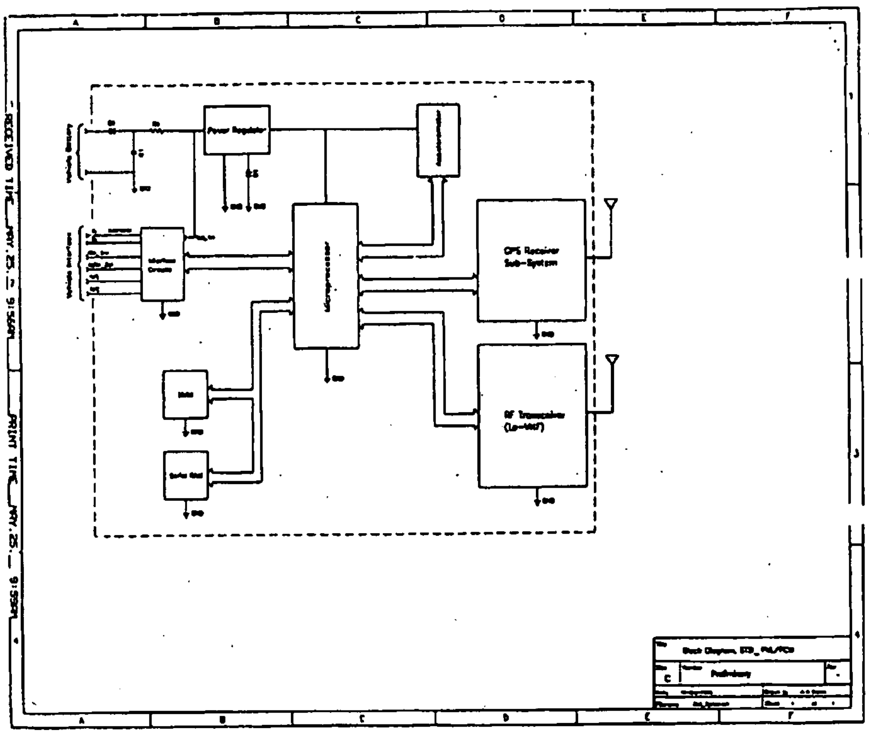
(54) **DISPOSITIF DE LOCALISATION DE VEHICULE**
(54) **VEHICLE LOCATING DEVICE**



Industrie Canada Industry Canada

VEHICLE LOCATING DEVICE

FIELD OF THE INVENTION

The present invention relates to a system that when installed and set-up in a vehicle, has the capability of electronically determining and reporting its geographical location (fix). The fix is determined using a Global Positioning System (GPS) module and the reporting function is via a separate radio frequency transceiver. The main role for the system is a "Passive Vehicle Locator" (PVL) device and the additional role being a "Passive Collision Notification" (PCN) collision detection system. A reporting station or monitoring service receives this data, and notifies the appropriate services if it is determined that the vehicle has been stolen.

Details concerning the reporting station are considered outside the scope of this invention as are details concerning the operation of the GPS system, other than the receipt and processing of positional data.

BACKGROUND OF THE INVENTION

A dramatic increase in vehicle theft (automobiles, snowmobiles, boats, aeroplanes, etc.), for vehicle or parts resale has lead to an increase in demand by owners, police and insurance carriers for a measure to track and recover the stolen property. The present invention provides a tool to help aid in the recovery of stolen vehicles.

By means of several radio frequency (RF) technology systems and a small system controller in the vehicle a watchful eye can be kept on ones' property through a monitoring service centre. Although it is not the design intent of the system to prevent the theft of the vehicle, measures are built into the system to prevent the vehicle from starting where possible. It will not prevent the theft of a vehicle if it were to be left running. The system will

communicate the vehicle's location and particulars to the monitoring service at the request of the monitoring service or when triggered by the in-vehicle system. The monitoring service can then notify the appropriate authorities.

The system operates in a total passive mode to the user. The primary function of the system is to continuously derive position fixes from a GPS receiver while the vehicle is operating and in the run mode and periodically when the vehicle is off. In the event of vehicle theft, the GPS data is transmitted through a lo-VHF transceiver system to a receiving station monitoring the vehicle's particular operational frequency and encoded data message. The GPS data is stored temporarily in system scratch pad memory and is routinely updated.

The added feature/function of the system is that of a collision and rate of movement detection system. By means of an onboard three axis accelerometer, shock and vibration data is continuously read while the vehicle is in the run mode and periodically when the vehicle is at rest. The system compares this data to programmed limits and acts accordingly when required. The system will communicate collision "g" force details to the monitoring service centre as well as the last fix.

SUMMARY OF THE INVENTION

The system of the present invention is an integrated assembly consisting of three minor components and/or subsystems contained to a rigid housing moulded of automotive grade plastics specific for the application. The complete system includes:

- Main Multifunction Control Module
- Custom wire harness assembly
- Rechargeable NiMh battery pack

- GPS receiver
- Lo-VHF transceiver
- System antennas

The two RF subsystems and antennae are of existing technology, registered to their respective companies and may be patented by those respective companies accordingly.

Main Multifunction Control Module (MCM)

The multifunction control module (MCM) is the primary control element and all features and system functions are controlled through this assembly. The MCM contains a three axis accelerometer-type sensor, a serial communication controller, a power regulator and battery control system, a non-volatile memory array and peripheral interface circuits. The core microprocessor has the built in feature of flash upgradeable memory.

The flash upgradeable memory allows updates to the operating system software contained within the core microprocessor.. It is updated through a simple instrumentation hook-up via an USB port. There is no need of an expensive module replacement as would be the case for masked embedded systems.

The MCM serves as the system motherboard for the entire system and allows the placement and connection of the two remaining RF subsystems and the connection of the NiMh backup battery. The system is connected to the various points of the vehicle through a custom wire harness assembly via the right angle header, J1, *(part of motherboard assembly)*.

The entire MCM is conformal coated with a high grade encapsulant type material reducing the effects and influence of environmental conditions, e.g.: dust, humidity, oil, grease and water *(see environmental specifications)*.

Global Positioning System Receiver

The global positioning receiver is an eight (8) channel receiver. Magellan Corporation are the suppliers of a suitable system.

The GPS receiver is an integrated assembly. The module is installed and connected through to the MCM and is held in place by mechanical stand-off fasteners and a vertical system connector.

The active GPS antennae is connected to the GPS receiver. The GPS receiver supplies the necessary power to the antennae system.

Lo-VHF Transceiver

The Lo-VHF transceiver is a bi-directional digital RF modem. The modem operates as similar to IEEE specification(s) RS232-C and is limited to a baud rate of 4800.

The transceiver is an integrated assembly. The module is installed and connected through to the MCM via mechanical stand-off fasteners and a system connector.

A transceiver suitable for the purposes of this system definition is that of a subsidiary company to Magellan Corporation.

Custom Wire Harness Assembly

The wire harness assembly consists of system automotive grade connectors and is fabricated using automotive electrical wiring and techniques. The gauge and rating of the wiring is as per standard automotive specifications and practices for use in passenger compartment and trunk deck.

The individual wires of the harness are colour coded to insure ease of installation and identification, thus reducing risk of potential errors.

Summary of Features and Functions:

- Motherboard design, flexibility of add-on module types
- Motherboard contains key system circuitry
- Integrated three (3) axis accelerometer used for impact/collision detection
- Integrated power supply and "Battery Run Down Protection"
- Integrated battery charge control system
- Standard automotive battery voltage range (9-16 Vdc.)
- Low standby current requirements
- Environmental conditions protected assemblies
- Electrical stress protected assemblies
- Ease of placement and installation to vehicle
- Extensive onboard system diagnostics
- Custom wire harness, matched to vehicle manufacturer
- Automotive grade custom wire harness assembly
- Flash memory capabilities type microprocessor, ease of update OS software
- Vehicle communication bus compatibility, J1850 or CAN 2.0 (J1850 & CAN 2.0 are in-vehicle structured bus protocol systems and respective specifications. Each manufacturer will have their own unique set of instructions and function per instruction list. Additionally not all vehicles will be equipped with systems; as such, connection to other alternate onboard systems will be required.)
- System connects and monitors installed alarm system status
- System operates in a total passive mode of operation

- Simplified system set-up and registration with monitoring service, completely automated and passive to user and technician.

BRIEF DESCRIPTION OF THE DRAWINGS

Drawings illustrating aspects of the present invention, by way of example are attached, in which:

Fig. 1 is a two satellite range diagram

Fig. 2 is a three satellite range diagram

Fig. 3 is a fix sampling rate graph

Fig. 4 is a schematic of the system of the present invention

DETAILED SYSTEM DESCRIPTION AND OPERATION

The Main Multifunction Control Module

GPS Module:

The purpose of the GPS receiver portion of the Multifunction Control Module is to determine the geographical position (fix) in degrees latitude and longitude of the receiver. The module receives signals from a series of geosynchronous satellites orbiting in precise locations over the earth.

The GPS receiver calculates the range from the receiver to each satellite. Once the range to a satellite is determined, it follows that the receiver lies somewhere on a sphere with its radius equal to the calculated range. The position of the satellite is the centre of that sphere. If the range to a second satellite is found, a second sphere can be superimposed around that satellite.

The receiver position now lies somewhere on the circle where the two spheres intersect (see figure 1).

This, it should be noted, is different than the circle of position concept in standard navigation terms as this circle is oriented with the centre axis ends coinciding with the position of the two satellites rather than the circle of position with a radius = 90°-h, with its axis oriented between a celestial body and the geographical position of that body. With a third satellite, the sphere intercepting the circle results in two common points, the location is reduced to two points (see figure 2). A fourth satellite therefore fixes the altitude of the receiver.

To determine the range from to the satellite, the receiver requires two variables: elapse time and speed. A continuous radio signal sent out by the satellites is picked up by the receiver which multiplies the speed of the signal by the time it took the signal to travel from the satellite to the receiver. The signal packet transmitted by the satellite is divided into a random sequence, each division being different from each other, called pseudo-random code (PRC). This random sequence is repeated continuously. The GPS receiver is programmed with this sequence and generates it internally. Therefore, satellites and the receivers must be synchronised. All GPS satellites have atomic clocks. The receiver picks up the satellite's transmission and compares the incoming signal to its own internal signal. A comparison of how much the satellite signal is lagging gives the travel elapse time, multiplication of this by the speed factor: c=2.997 924 58 x 10^8 ms^{-1}, the official WGS-84 speed of light, determines the distance or range to that satellite.

GPS error:

The spherical radii of the satellite signals are determined for the three or four different satellites. With the pseudorandom code, the satellite transmits its orbital position data or

almanac. The GPS constellation is monitored by the Master Control Station at Schriever Air Force Base (formerly known as Falcon Air Force Base). Using data collected by five monitor stations distributed around the globe, MCS assesses GPS performance every 15 minutes by conducting tolerance and validation checks of the measured pseudoranges using a Kalman-filter, error-management process. Variations in the orbit of the satellite are transmitted to the satellite which incorporates these deviations in its position signal. If the satellite experiences errors or malfunctions, the MCS instructs these satellites to transmit false data which comes up as unreadable to ICP compliant GPS receivers. Those receivers will ignore data from those satellites and "look" for a satellite set with healthy data. The receiver receives this data and internally "positions" the spheres. The intercepting circles and points of position are then determined and outputted as geographical positions, latitude, longitude and altitude.

Several brands of receivers have the capability to track as many as twelve satellites (channels) simultaneously, the advantage being that they can select two or three sets of satellites that have the best "cut" or azimuth angle characteristics as well as healthy almanac data. Horizontal Dilution of Precision (HDOP) is caused by a poor satellite set angle geometry. If the GPS receiver is using satellites in the same area of the sky as opposed to being distributed across the horizon, the location of the receiver becomes increasingly uncertain. Thus a good geometric position, or cut between each of the satellites around the earth's horizon would be 120°.

The US DoD operates the GPS system. Since precise geographical position data could potentially be used contrary to America's best interest, a deliberate degradation is created by introducing a random digital distortion. Selective Availability (SA) of the signals sent by each satellite. This degradation so not to make the system unusable, is closely controlled but occurs over random periods of time. Over a period of 24 hours the effect of the randomly introduced

errors cancel out so a 'true' position will be available as long as the receiver is stationary for the full period. Another deviation deliberately introduced is slightly inaccurate satellite position data transmitted by the satellite. Also the 'true' receiver location will be subject to variations in physical factors such as ionosphere errors over which the DoD has no control. Thus the standard precision that can be expected from an uncorrected GPS receiver is ± 100 metres 95% of the time. For the purposes of the STSI module, this is considered an acceptable level of precision.

SA corrections are transmitted from various land based beacons. These correction factors account for ephemeris (satellite orbit) error, satellite clock error, etc. based on the fact that the land based beacons are fixed and their positions precisely known. These beacons receive the standard GPS signals, calculate the satellite errors and SA effects and transmits these corrections. These corrections are received by specially equipped receivers. Differential GPS and the fix precision can increase to sub-metre accuracy.

GPS sampling rate:

The MCM routinely accesses a GPS fix and stores it into memory. The rate of which the fix is accessed is inversely proportional to the speed of the vehicle. That is, the fix sampling occurs more often when the vehicle is travelling at a slow rate of speed, and less often when the vehicle is travelling at a higher speed. The speed of the vehicle can be determined any number of ways, by GPS sampling, or from the vehicle's own data bus, by external sensor or takeoff from the vehicle's instrumentation. The sampling rate or "Update Factor" relationship is illustrated in figure 3.

If the MCM experiences an acceleration (or deceleration) greater than a preset threshold (about 5 g's) over a maximum elapse time, the system will immediately try to acquire a fix from

the GPS and store this to the NVM. In such a case the MCM is designed to aid in collision location. In addition to the location and time, the MCM can be additionally programmed to record the previous speed, time, course (direction) and other parameters over the past four samples.

The most recent fix is entered into the non-volatile Memory (NVM) as FIX 1, indexing the preceding fix to FIX 2, the previous fix before that one to FIX 3 and so on. The previous FIX 4 is discarded. The NVM has the capacity to record four fixes, or the course of the receiver from four fixes back. Optionally, depending on programming, the MCM will estimate a Dead Reckoning (DR) position based on speed and bearing. This would be used if the GPS receiver was unable to acquire a usable fix: the antenna was shielded from satellites, or the unit suffered a power interruption and was performing a boot (warm) at the time.

The inverse sampling rate is a result of the fact that the interrogation routine runs on a fixed time base. There are several pickups or data inputs that have to be read on a routine basis. These would include the vehicle speed sensor (probably of the vehicle bus), the GPS module, the brake input, and the crash sensors or accelerometer(s). This routine is accomplished during a fixed time which is not varied. For instance, the time between data updates from the GPS could be 200 ms, no matter the velocity the vehicle is travelling at. Thus the faster the vehicle travels, the greater distance it will cover in 200 ms compared to if it was travelling 50% or 10% of that speed. Therefore, there is an inverse relationship between vehicle distance travelled per unit time (speed) and update rate.

The module can also be programmed to output (calculate) the receiver's speed, bearing, and time, either local or UTC. The speed can be calculated to be either Kilometres/hour, Statute

miles/hour or Nautical miles/hour. The bearing can be programmed to be degrees from True or grid (Mercator) north.

Crash sensor:

The function of crash sensor in the MCM of the present invention is to trigger the Lo-VHF transmitter whenever the receiver undergoes an acceleration (change of velocity) exceeding a specific programmed threshold. Although, not considered a primary safety component, the crash sensor's functional characteristics and theory of operation will closely parallel that of airbag deployment sensors. Thus airbag deploying sensing technique and design rationale is considered applicable to our design.

Crash sensors are typically electromechanical transducers that convert variations in kenimatic parameters (vehicle velocity and its derivatives) to an electrical signal. Two general types are in use: electromechanical switches that close an electrical contact at some specified signal level (typically the change in vehicle velocity) and analogue sensors that provide an output voltage proportional to signal input (such as acceleration). Switches open or close an electrical switch, while accelerometers can provide a large amount of data (a few hundred points) during a crash event.

Electromechanical switches typically are over damped spring-mass or magnetic systems that trigger after a specific change in vehicle velocity. Switches are placed in a number of areas, including the vehicle's frontal crush zone. In this way, the switch will trigger at a specific accident event, well in advance of that signal level being felt in the occupant compartment. Other configurations for switching are rolling ball bearing types that make contact when a conductive ball rolls over two contact plates. The ball is initially held in place by a magnet, an acceleration

of sufficient force overcomes the magnetic lock and causes the ball to roll to the contacts. These sensors are available in one, two and three axis configurations. The contacts are Normally Open.

In the present invention, it is optional to install either distributed electromechanical crash sensors (switches) or a single- (or dual) axis accelerometers located in or around the passenger compartment. In the automotive industry, multiple crush-zone sensors are now being replaced by a single analogue accelerometer or single-point sensor. The reason is to reduce costs associated with the sensors and installation. Placing the sensor in the occupant compartment simplifies installation (i.e., reduces the cost) compared to multiple crush-zone mounted sensors. Also, it serves to reduce the wiring being run to these vulnerable areas of the vehicle and thus improve reliability. Because the sensor is situated in a relatively benign environment, there is less risk of malfunction of the sensor and its wiring. An analogue accelerometer also provides. a much larger volume of data with which to predict incident class. With analytical software, the type of incident and severity can be assessed by the MCM and appropriate programmed action taken, i.e., accident type of signature or break in type of signature. Processing of these data allows high-fidelity records of acceleration (in the case of analogue accelerometers) on a time scale in most cases. Trip thresholds may be adjusted through software rather than the mechanical modification required for electromechanical switches.

Although single-point sensing is becoming quite common, there are certain vehicle platforms that may still require multiple sensors. This will be because of the inability of a single sensor to provide reliable impact detection for all crash scenarios. Some light trucks and Mini vans which have less side impact pillars may crumple and incapacitate the driver without the accelerometer experiencing a typical crash signature. Also, soft vehicle structures in narrow-

object crashes (i.e. a Corvette head-on into a narrow concrete bollard), and possibly others could lead to variable MCM trigger reactions.

Thus it is the primary intent to install a single axis accelerometer into the MCM and place the MCM in areas that are likely to remain undeformed during a crash and that will not resonate during the crash. Sensor placement is a critical step in the tuning process, where the vehicle crush characteristics over a wide range of crash pulses must be accounted for. Preferably, the crash sensor is mounted to the vehicle centreline behind the firewall, on a structural component such as a strut or brace.

The sensor utilized in the present invention may be a Motorola MMAS40G. The MMAS40G incorporates a single polysilicone mass suspended between two fixed polysilicone plates. The forces of acceleration causes the mass to move against the plates cuaing a change in capacitance. The unit has built in damping.

The Motorola accelerometers are single axis package, and comes in 16 pin DIP and 8 pin SIP package. The MCM will require two SIP package accelerometers for X and Y impact detection and a DIP package for Z axis impact or rollover detection.

The Vehicle rollover can be detected by discrete rollover sensors. Rollover sensors operate through rolling ball or accelerometer technology. The rolling ball technology employs a highly damped conductive ball housed in a sealed enclosure. The enclosure contains electrical contacts at the top end of the housing when in normal orientation. These contact leads are connected to leads at the bottom of the housing for mounting to a printed circuit board. When inverted, the ball sinks to the contact end where is mates and electrically connects two contacts. The closing of these contacts triggers the transceiver reporting protocols.

Rollover can also be detected by the accelerometer if 3-axis sensing is employed. Normally, at rest, the accelerometer will experience 1g in the Z-axis. Normal driving and operation of the vehicle will not produce any less downward accelerations for any significant length of time. In the case of a rollover, the vehicle is expected to undergo a series of violent swings in the forces acting in the Z axis. Thus the analytical software should be able to discern a rollover signature, and start the vehicle location reporting process.

Custom Harness:

The custom harness for the system of the present invention is to interconnect the various sensors (if any) to the MCM, as well as supply ±12Vdc. It will also include antennae required for the GPS and Lo-VHF transceivers.

The main harness is an assembly of special automotive grade connectors interconnected with wires of specific specification and length. A central harness plugs into the MCM unit, and is terminated with various connectors. Various extension harnesses allow connection of the central harness to optional remote sensors, power and ignition pickup points.

The antennae wires will also emanate from the MCM unit. Special coaxial type connectors may be employed to connect the antennae leads into the MCM enclosure.

Brake input:

Derived from the vehicle system bus, the brake input can be used in conjunction with the crash sensors for accident reconstruction. The data stored in the memory would indicate speed at which the brakes were applied, rate of deceleration, speed of impact, etc. This input can also

be derived from the brake pedal switch. There are many techniques in place to detect brake input and brake pedal position.

Vehicle speed sensor:

The speed sensor of the vehicle is usually a magnetic pickup integrated into the rear of the transmission and reads the teeth of a gear connected to the drive shaft of the vehicle. The signal from this sensor is sent back to the Engine Management System which then can control such things as fuel flow, spark advance, etc. The speed input signal would be used by the present invention for such things as look ahead algorithms, accident reconstruction, etc.

The look ahead algorithm is incorporated to predict where the vehicle should be within a certain time period, much like a Dead Reckoning (DR) position. Thus if the GPS signal is blocked or it was not capable of delivering a good fix, the MCM would "Predict" the next position, based on its last known fix, speed and bearing. The technique for predicting the next position could be based on one of several techniques, such as cosine law or meridonal parts. It would be able to deliver a usable DR position this for only a short elapse time as change in bearing or altitude would not be compensated for (unless a flux gate compass feature was incorporated). As soon as the GPS module is able to deliver a good fix, the DR position would be thrown out. Otherwise, this data would be stored and relayed as part of the distress data package.

Enclosure:

The enclosure of the MCM contains the main circuit board and the plugged on daughter boards (GPS receiver and the Lo-VHF transceiver). The enclosure is a plastic moulded assembly

consisting of a top and bottom half with optional side inserts for various connector configurations.

The bottom half is characterised by the protrusion of several reinforced mounting tabs or feet and or various through holes for screw mounting to the vehicle. Moulded inside the bottom half are mounting bosses and guides for securing the circuit boards. Reinforcing ribs are also integral to the bottom half for stiffness and strength. The tray is designed to accommodate a layer of conformal coating and or encapsulation if necessary.

The top half of the enclosure is moulded to complement the bottom half and to be ultrasonically welded to the bottom. Reinforcing ribs and structures provide strength and stiffness, and support for the daughter boards, connectors and auxiliary equipment. Also, after welding the assembly together, the result is a very stiff and watertight enclosure.

The plastic material used well be an engineering thermoplastic with up to a 20% glass content. This maximum amount of glass content is to facilitate ultrasonic welding. More glass content will tend to impede ultrasonic welding processes.

Lo-VHF Transceiver:

The Lo-VHF transceiver is a bi-directional digital RF modem. The modem operates as similar to IEEE specification(s) RS232-C and is limited to a baud rate of 4800. The system communicates directly with the Low Earth Orbit Satellites (LEOS) providing a continental coverage and to include those areas within Europe and South America and portions of the far east.

The transceiver is an integrated assembly, the module is installed and connected through to the MCM via mechanical stand-off fasteners and a system connector.

The transceiver selected for the purposes of this system definition is that of a subsidiary company to Magellan Corporation.

GPS receiver:

Non differential Global Positioning System receiver. Standard fix accurace, ± 100m, 95% of the time (± 0° 00.053996' of arc of a degree of longitude at L 0° 00.0' N)

Fix update: 1 to 99 sec, user selectable.

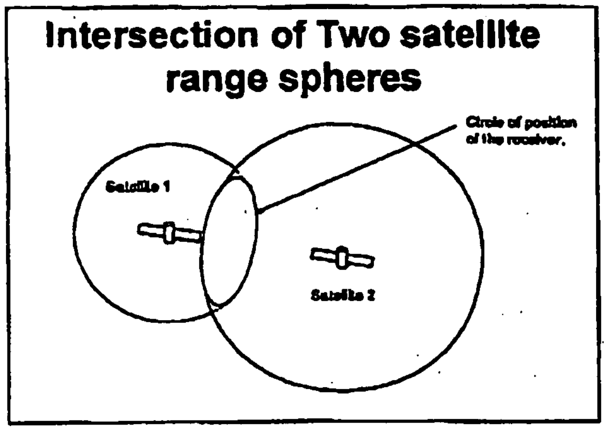


Figure 1: Possible receiver circle of position based on 2 satellites' range acquisition.

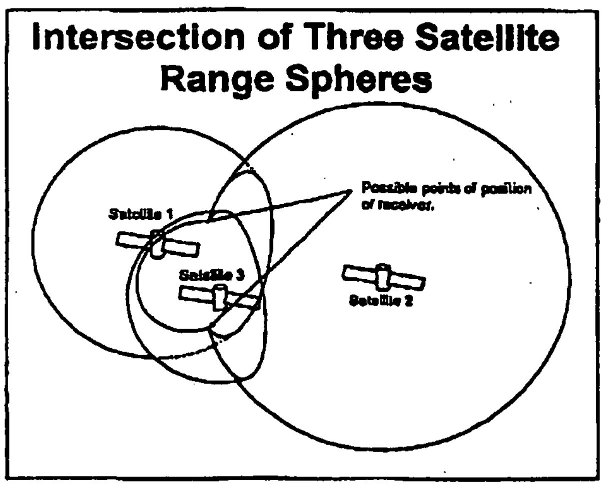


Figure 2: Possible receiver positions based on 3 satellites' range acquisition.

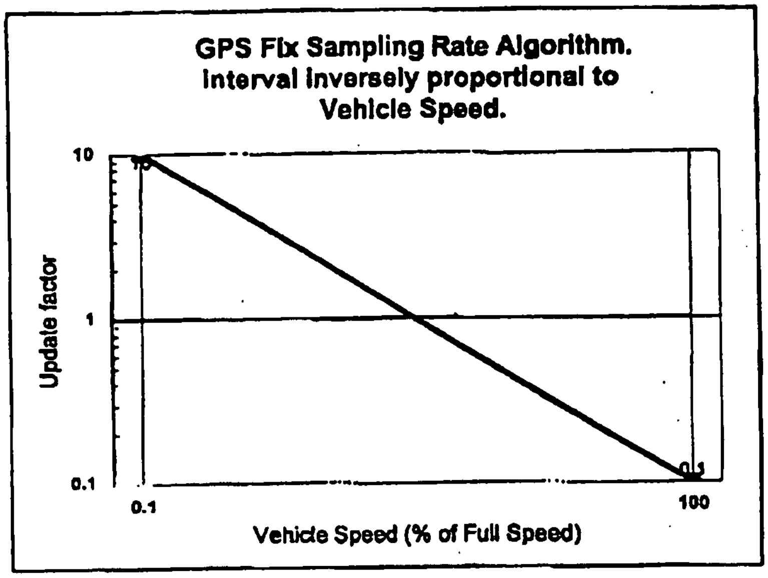


Figure 3: Fix Sampling Rate.

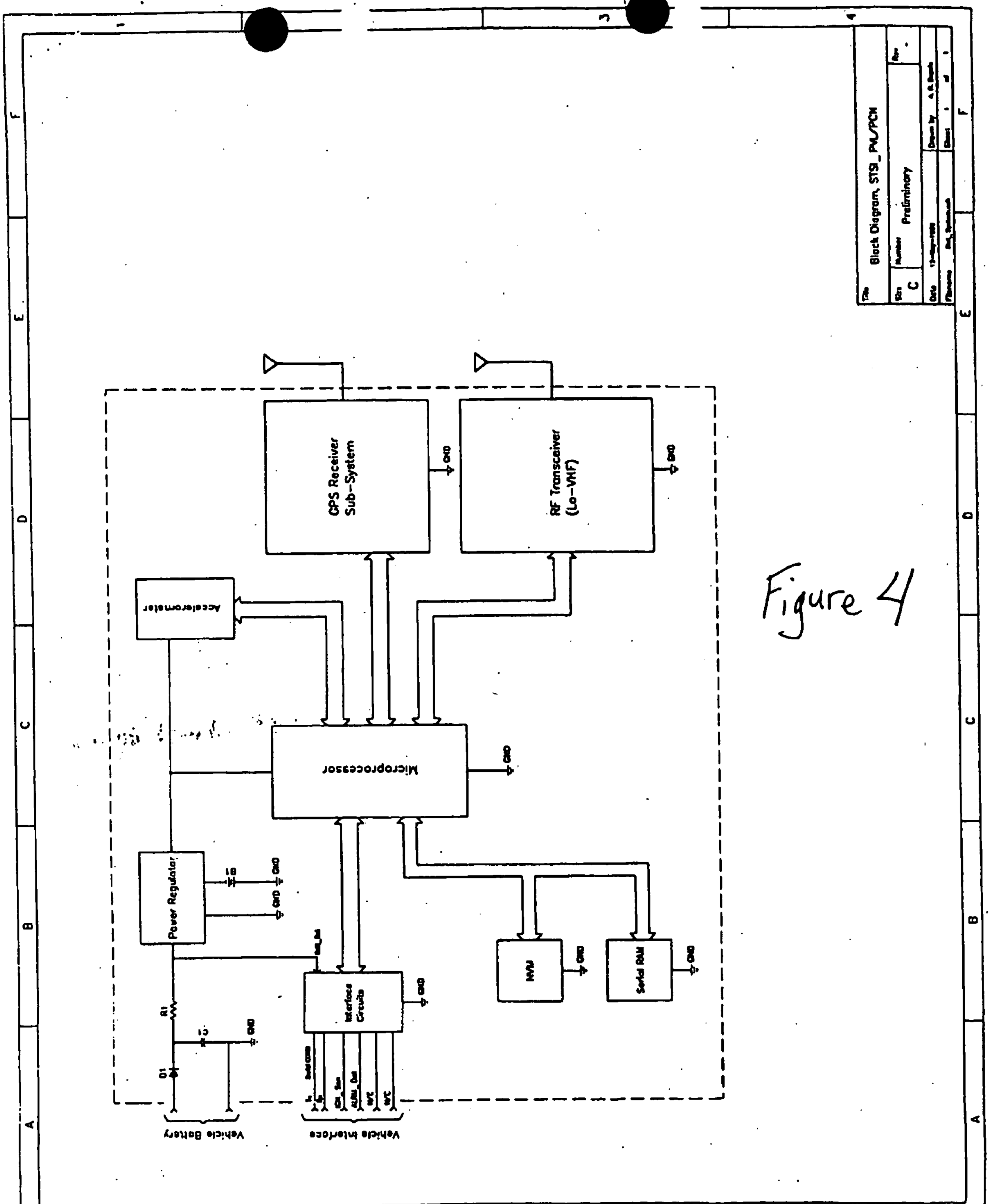

Block Diagram, STSI_PVL/PCN
Preliminary
GPS Receiver Sub-System
RF Transceiver (Lo-VHF)
Accelerometer
Microprocessor
Power Regulator
Interface Circuits
Serial RAM
Vehicle Battery
Vehicle Interface
GND

Figure 4